ASSESSING NITROGEN LEACHING FROM CROPPING SYSTEMS USING A NUTRIENT BUDGET MODEL

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Introduction

Concerns about the environmental impact of agricultural land use intensification mean that farmers are increasingly required to demonstrate that their soil nutrient management does not have an adverse effect on the environment. In New Zealand, current and proposed regulations suggest or require growers to estimate N leaching losses using an approved nutrient management tool. A tool currently available for such purpose is the OVERSEER® nutrient budgeting model (Wheeler et al., 2003). However, the development of this model has been especially focused on pastoral systems. Its cropping module is neither robust nor easy enough to use to be adopted on a scale required for compliancy (Agricultural Nitrogen Managers Group, 2006), and a major upgrade on the mechanism and interface of this module was suggested. Thus, a project involving representatives of the industry, Regional Councils, and research providers was started to develop a model with flexibility enough to handle realistic crop rotations and management, and yet, simple to use, and requiring a minimum of inputs which are meaningful to end-users.

A challenging aspect of the project was the lack of appropriate long-term measured datasets to develop the model. To overcome this, the model was devised and parameterised using results from a comprehensive modelling experiment using a process-based model, the LUCI model framework (Zyskowski et al., 2007). The basic developmental procedure of the upgraded nutrient budget model is presented here. Also shown is an evaluation test against independently generated dataset using the LUCI model.

Materials and Methods

In the proposed model, leaching was defined as the amount of N percolated below 1.5 m depth. The calculations are done on a monthly time-step in order to capture with greater detail the effects of plant growth and management. The user specifies the rotation and management practices over two years, the sum of N leaching in the second year is the value reported by the tool. The model concept is briefly presented here, details can be found in Wheeler et al. (2009).

For each month (m), the model initially computes the water balance (Eq. 1) based on average weather data and user inputs about soil type and irrigation schedule. Then, the N balance (Eq. 2) is calculated, based on the rotation and fertiliser applications set by the user.

$$W_{SOIL(m)} = W_{SOIL(m\text{-}1)}+(W_{RAIN(m)}+W_{IRRIGATION(m)})-(W_{EVAPORATION(m)}+W_{TRANSPIRATION(m)}+W_{DRAINAGE(m)}) \quad (1)$$

$$N_{SOIL(m)} = N_{SOIL(m\text{-}1)}+(N_{RAIN(m)}+N_{IRRIGATION(m)}+N_{FERTILISER(m)}+N_{ORGMATTER(m)}+N_{RESIDUES(m)}+N_{IRRIGATION(m)}) - (N_{VOLATILIZATION(m)}+N_{DENITRIFICATION(m)}+N_{UPTAKE(m)}+N_{LEACHING(m)}) \quad (2)$$

Plant N demand and the main processes related to the N balance, such as mineralization of soil organic matter ($N_{ORGMATTER}$) and crop residues ($N_{RESIDUES}$), are calculated using empirical relationships derived from simulations using the LUCI model. N leaching is computed in relation to the ratio of drainage, scaled to the soil water storage at field capacity (θ_{FC}), and the amount of mineral N in the soil using an exponential function (Eq. 3), which was also derived from LUCI simulations. Its parameters (α and β) are soil specific.

$$N_{LEACHING(m)} = N_{SOIL(m)}\,\alpha(W_{DRAINAGE(m)}/\theta_{FC})^{\beta} \quad (3)$$

Comparisons of predictions from the proposed model against a dataset obtained from a simulation experiment using the LUCI model was used to test the model. A factorial combination of two soil types (light or heavy texture), four land uses (fallow, spring and autumn wheat, and potato), three irrigation regimes (0, 300, and 600 mm) and three fertiliser rates (0, 150 and 450 kg ha^{-1}) were used with 25 years of actual weather data from three locations in New Zealand (Pukekohe, Hastings, and Gore). Annual values of the components of the water and N balances were compiled for the analyses. Drainage, and N leaching results are shown here.

Results

The water balance was described sufficiently well by the proposed model. Evapotranspiration estimates showed some scatter, but the estimates of drainage using the simple model agreed pretty well (R^2 = 0.95) with the results from the LUCI model (Fig. 1).

The estimates of N leaching also showed a reasonably good agreement between the two models (Fig. 1). The scatter is a bit greater for leaching than that of drainage, especially for the tests using crops. Nonetheless the R^2 value of 0.94 shows that the simple model does a good job to describe an output which typically shows high natural variability.

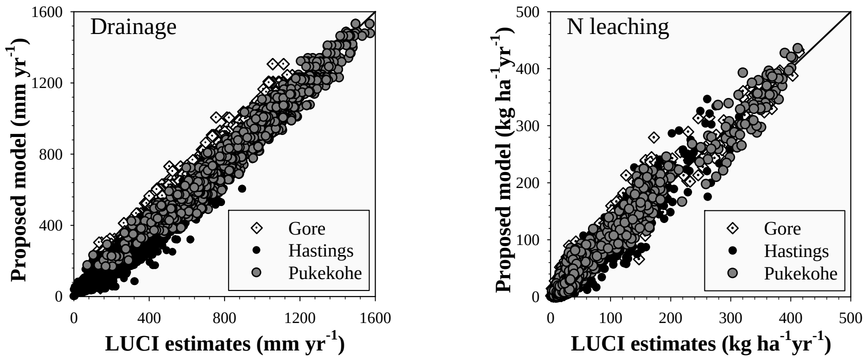

Fig. 1. Comparison between the annual values of drainage and N leaching estimated by the proposed model and the LUCI framework for a series of scenarios in three sites in New Zealand.

Conclusions

The model presented here exhibited good performance when compared to a more detailed model. The developed tool is robust and easy to use, thus well suited to assist on N management and to provide environmental accountability in cropping systems. It has been incorporated as an upgrade of the OVERSEER® nutrient budget model and is available for use by farmers, consultants and Regional Councils in New Zealand. With calculation made on a monthly basis, the model is expected to be responsive to year-to-year variations, as shown in the tests against the LUCI model. However, comparisons against short-term data should be done with caution, as the relationships were derived for long-term averages. Also it is important to notice that the model presented here was devised to estimate N outputs of relatively stable farm systems which are managed following best management practices. Using accordingly, the proposed model should be sufficient for growers to provide evidence of good nutrient management practice.

References

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